# Modeling of the Urban Heat Island:

# Assessment of mitigation strategies for the City of Stuttgart

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# Overview

- ***CENTRAL Europe Project**:*

  *‚Development and application of mitigation and adaptation strategies counteracting the Urban Heat Island (UHI).‘* (European Territorial Cooperation Objective CENTRAL EUROPE Programme - 3CE292P3)
- **Mesoscale numerical modeling (WRF)** of the UHI for selected Region:
  - Urbanization of WRF → Selection of most suited urbanization scheme
- **Validation** of modeling results through measurement data
- **Simulation** of simple mitigation strategies
  - Change of land surface properties
- UHI triggers **secondary circulation**

  → Urban-Rural interaction

  → Air Quality assessment
- *Assistance to Urban Planning (local stakeholders, City of Stuttgart)*


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# Model approach

- Choosing the WRF/urban parameterization scheme suitable for the modeling approach (coupled with Noah LSM)
  - Single Layer Urban Canopy Model SLUCM (KUSAKA, 2001)
  - Building Energy Parameterization BEP (MARTILLI, 2002)

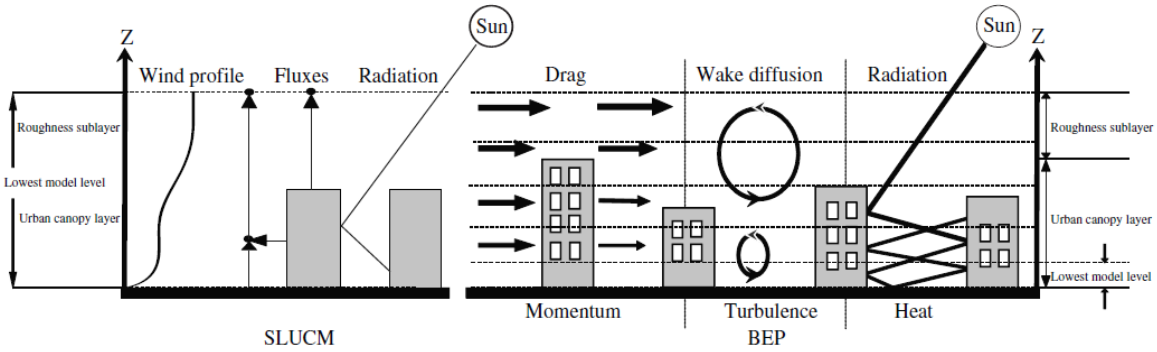


***Fig. 1:*** *Schematic of SLUCM (left) and multi-layer-BEP (right) (CHEN, 2011)*

- Replace urban land use classes by natural vegetation
- Change albedo of urban surfaces, building densities etc.
- Comparing temperature development under different scenarios


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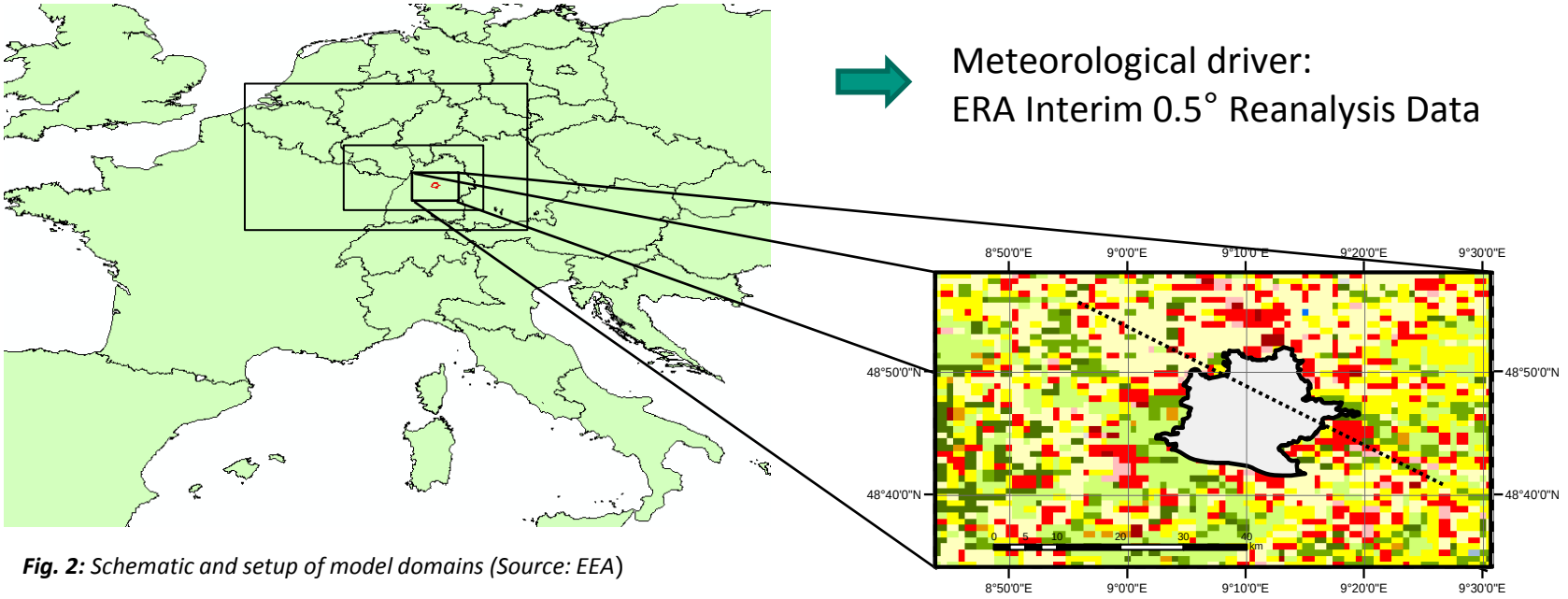
# WRF Configuration




Meteorological driver:
ERA Interim 0.5° Reanalysis Data

***Fig. 2:*** *Schematic and setup of model domains (Source: EEA)*

| Domain | D01 | D02 | D03 |
|---|---|---|---|
| Geographical input data | 1km | 1km | 1km |
| dx, dy | 15 | 3 | 1 |
| West-east [km] | 645 | 228 | 61 |
| North-south [km] | 510 | 168 | 49 |
| Total [km²] | 328950 | 38304 | 2989 |

**Corine Land Cover**

- 2-Dryland Cropland and Pasture
- 3-Irrigated Cropland and Pasture
- 4-Mixed Cropland
- 7-Grassland
- 11-Deciduous Broadleaf Forrest
- 14-Evergreen Needleleaf Forrest
- 15-Mixed Forrest
- 16-Water
- 17-Herbaceous Wetland
- 18-Wooded Wetland
- 19-Sparsely Vegetated, Barren
- 24-Snow
- 25-Playa
- 31-Low Intensity Residential
- 32-High Intensity Residential
- 33-Industrial/ Commercial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# WRF Configuration

- WRF Single Moment 6-class scheme
- RRTM long wave radiation
- Dudhia short wave radiation
- Eta similarity surface layer
- NOAH Land Surface Model
- Mellor-Yamada-Janjic (MYJ) boundary layer scheme
- Kain-Fritsch scheme for cumulus parameterization (1st domain)
- Building-Energy parameterization (BEP) / Single Layer Urban Canopy Model (SLUCM)


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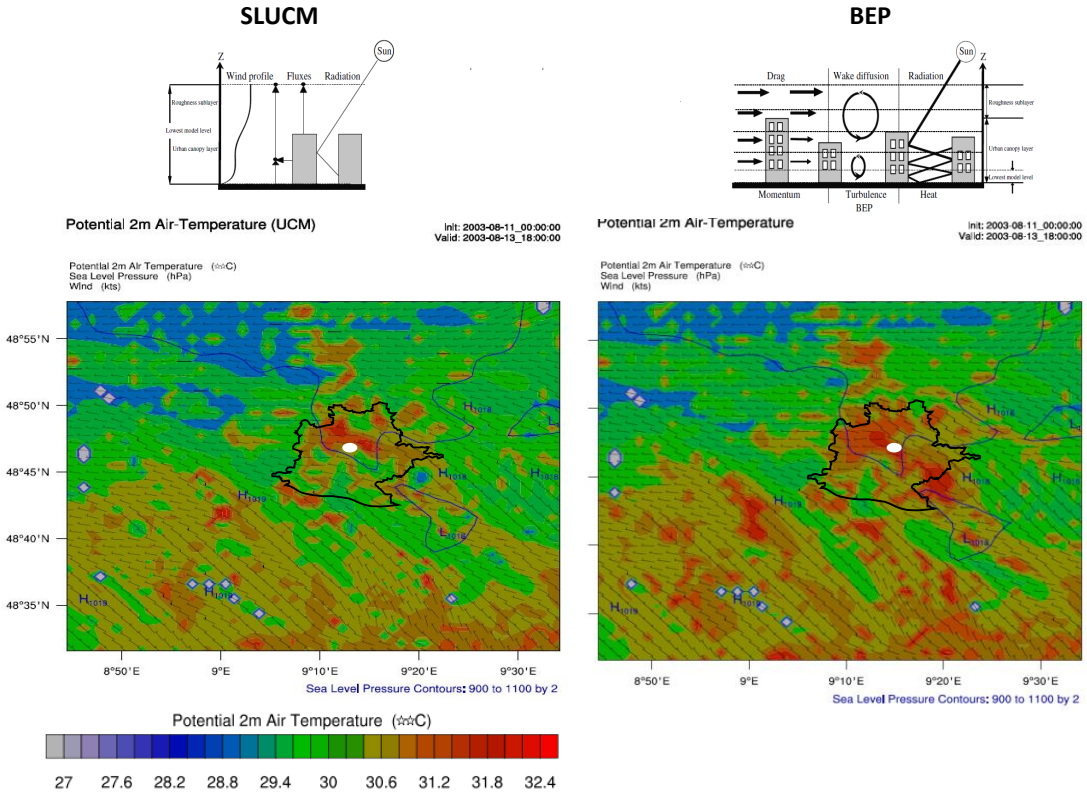
# Validation



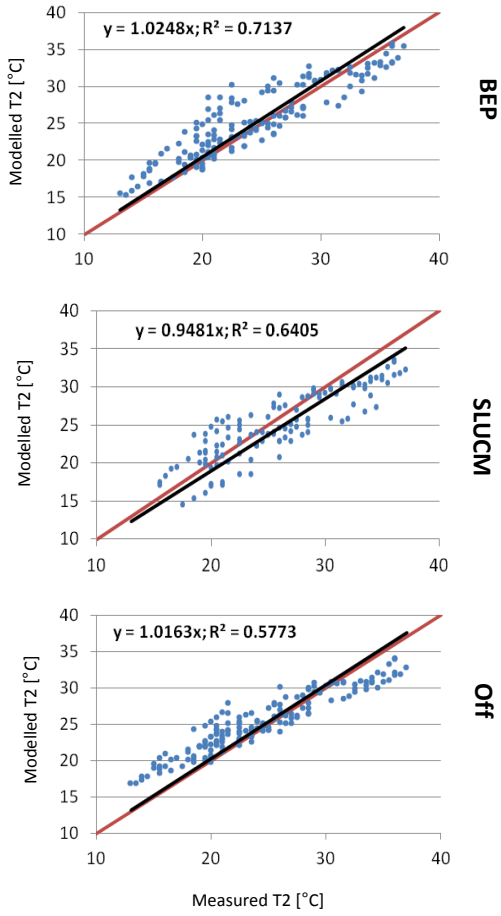




***Fig. 3:*** *Simulated 2m air temperature for **SLUCM** (left) and **BEP** (right) – Comparison with data from measurement station Bad Cannstadt visible through correlation plots (right)*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# Land use change to test urban effects

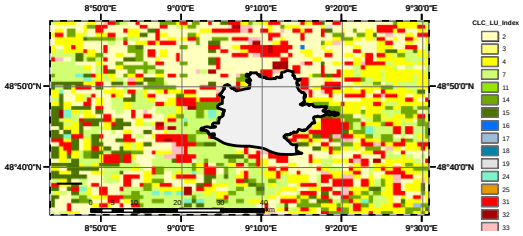


***Fig. 4**: changed land use type in between the urban area of Stuttgart for 3rd domain*

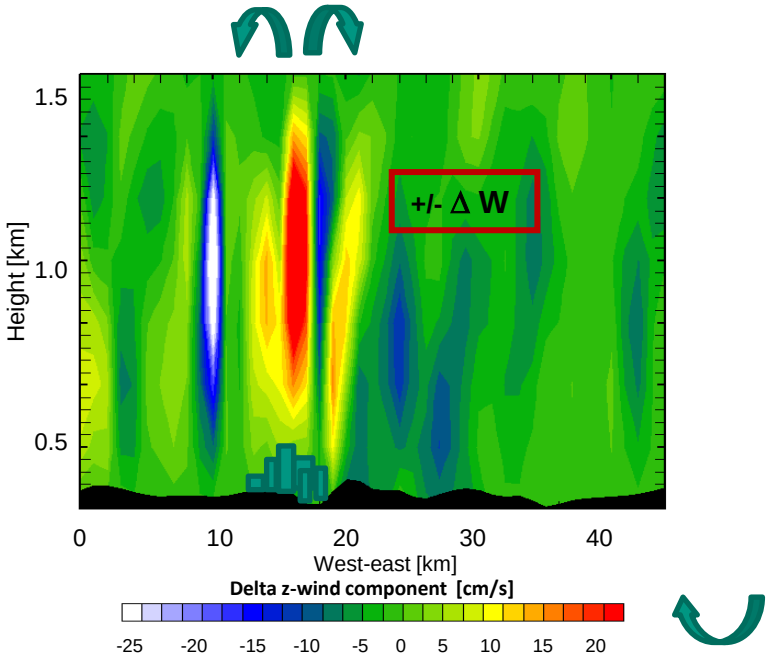


***Fig. 6:** Characteristic circulation patterns through urban-rural interaction*

Urban = 'on'

Urban = 'off'

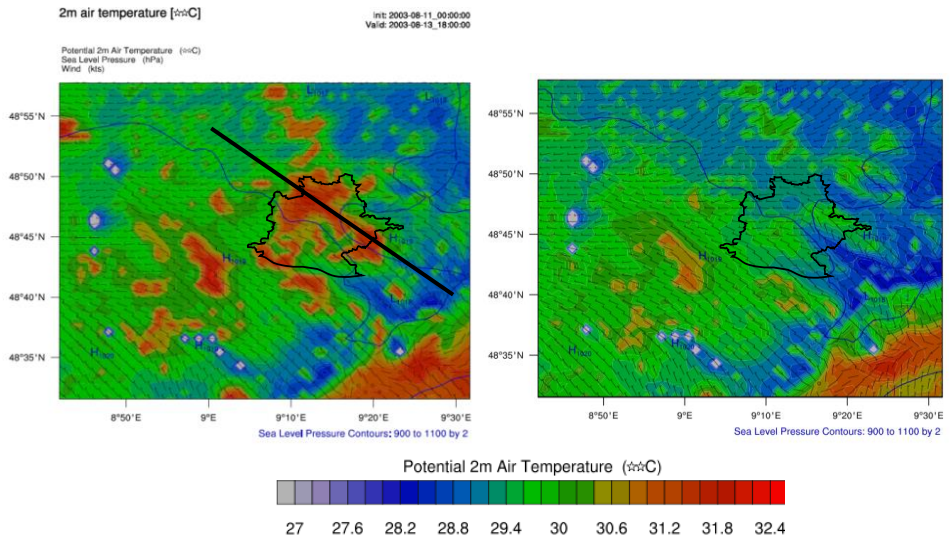


***Fig. 5:** Potential 2m air temperature – early evening in summer – Snapshot for **Aug 13th 2003 18:00***



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# Urban planning mitigation scenarios - area

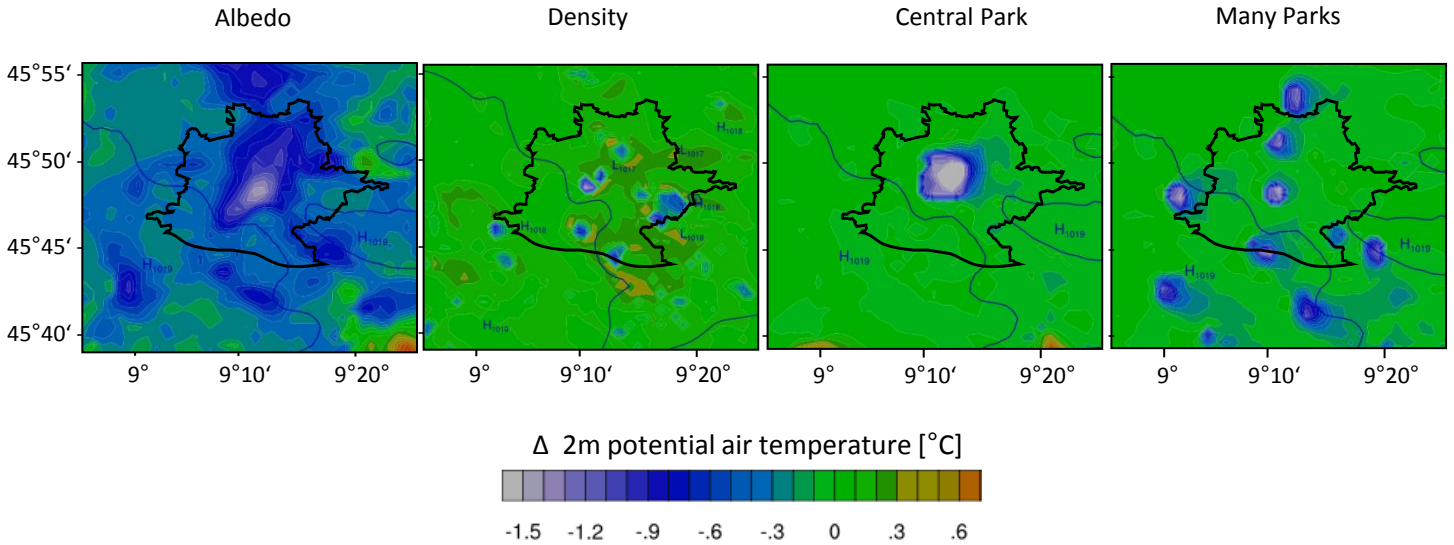


***Fig. 7**: Effect of urban planning strategy on WRF potential air temperature – scenario case compared to ‘real’ case (WRF-BEP) for Aug 13th 2003 18:00; up to 6% temperature reduction on average*

| Scenario | Albedo | Density | Many Parks | Big Park | Real Case |
|---|---|---|---|---|---|
| T mean urban [°C] | 32 | 32.4 | 32.46 | 32.34 | 33.1 |
| T max [°C] | 32.7 | 33 | 33.5 | 33.3 | 34.3 |
| Std dev. [°C] | 0.32 | 0.48 | 0.52 | 0.42 | 0.5 |
| UHI; ΔT [°C] | **0.84** | **1.32** | **1.47** | **1.19** | **2.52** |

***Tab. 1**: Effect of mitigation strategy on averaged temperature over the urban area and UHI Intensity*


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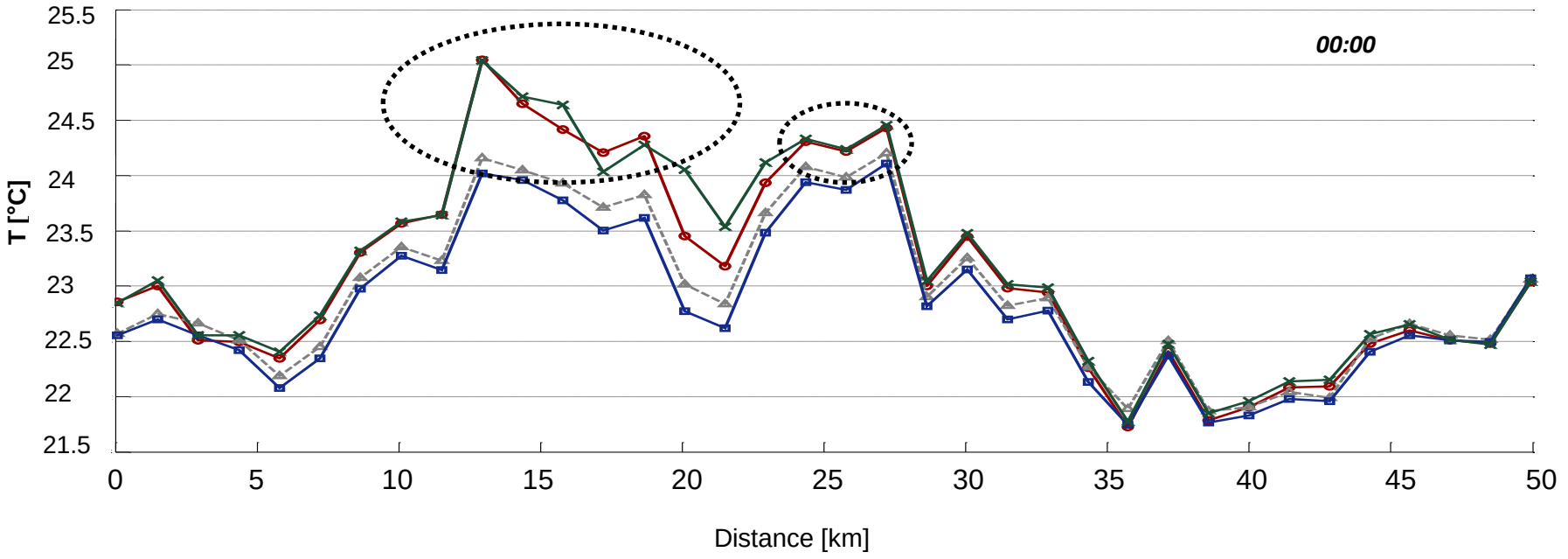
# Urban planning mitigation scenarios - transect



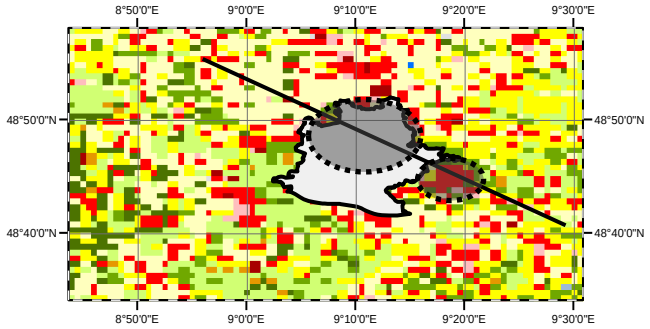




***Fig. 8**: Development of potential 2m air temperature for west-east transect after applying mitigation strategy – Aug 13th 2003 00:00*



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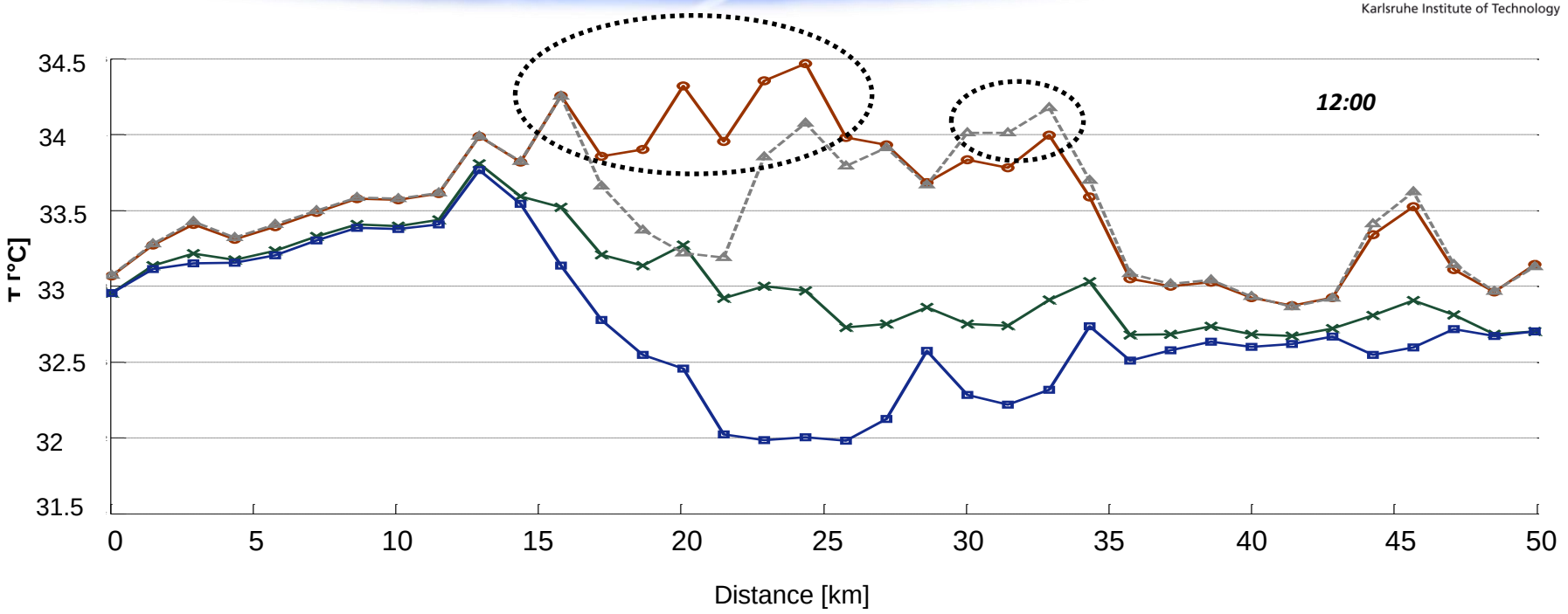
# Urban planning mitigation scenarios - transect



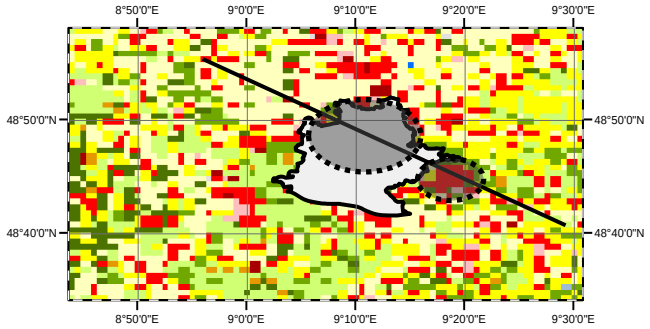




***Fig. 9**: Development of potential temperature for west-east transect after applying mitigation strategy – Aug 13th 2003 12:00*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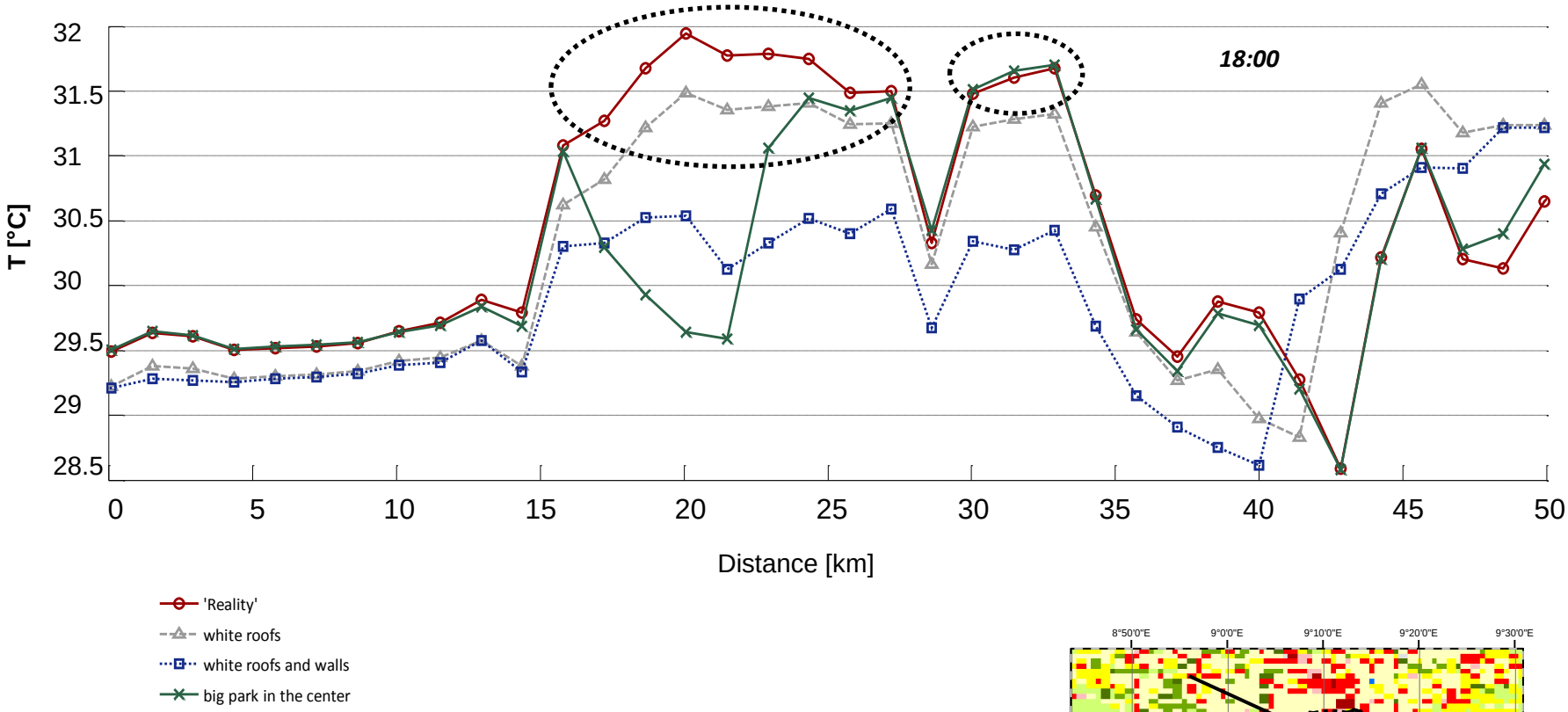
# Urban planning mitigation scenarios - transect



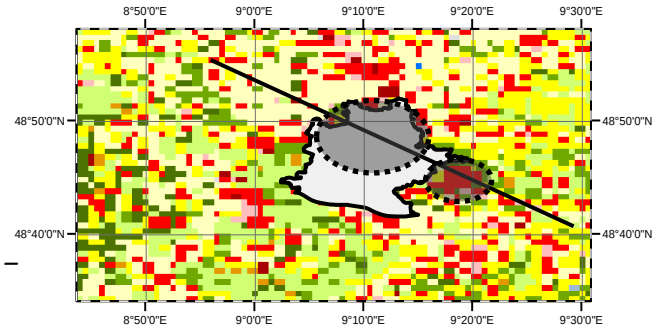




***Fig. 10**: Development of potential temperature for west-east transect after applying mitigation strategy – Aug 13th 2003 18:00*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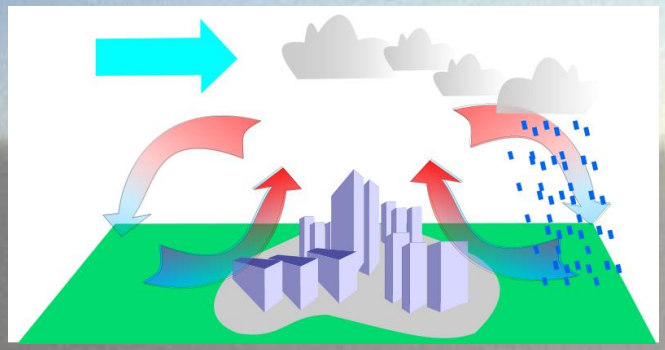
# The need for air quality modelling…



UV - Radiation

1) $NO_2 \longrightarrow NO + O$

2) $O + O_2 \longrightarrow O_3$

invers03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# Thank you for your attention

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